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# STRESS CORROSION FAILURE OF A LOW PRESSURE DISK FROM A 800 MW STEAM TURBINE


Anthony Tipton

Thielsch Engineering, Inc.


TURBOMACHINERY LABORATORY
TEXAS A&M ENGINEERING EXPERIMENT STATION

TEXAS A&M UNIVERSITY

# Author bio

Anthony Tipton is a Senior Staff Engineer at Thielsch Engineering. During his 32 year career, Mr. Tipton has been intimately involved in the design, development and manufacture of rotating equipment including gas turbines, steam turbines, gas expanders and compressors.

Mr. Tipton has previously held technical and management positions with Pratt & Whitney Aircraft, Hamilton-Sundstrand, Dresser-Rand, Westinghouse Electric and the Tennessee Valley Authority.

Anthony received a Bachelor of Science Degree in Metallurgy and Materials Engineering from Lehigh University and a Master of Science Degree in Metallurgy and Materials Science from Rensselaer Polytechnic Institute. He is a member of the American Society for Testing and Materials (ASTM) and the American Society of Mechanical Engineers (ASME).

# Abstract

Stress corrosion cracking is known to be a function of stress, material and environment. However, a fourth variable that is often overlooked is operating time. Maintaining steam chemistry within OEM and industry guidelines is not sufficient to prevent stress corrosion cracking in high stress locations such as the blade attachments of older low pressure turbine disks. Resulting stress corrosion failures occur without warning and generally result in significant secondary damage and unit downtime. Non-destructive examination has been used to identify stress corrosion cracking however, many blade attachment designs are not conducive to inspection without complete removal of blading.

This case study discusses the root cause analysis of a recent stress corrosion failure of a low pressure disk from a 800 MW steam turbine. Turbine disk modifications to prevent future stress corrosion cracking are detailed.

# Background

- Tandem Compound Steam Turbine Generator
  - Arrangement
    - High Pressure Turbine
    - Double Flow Intermediate Pressure Turbine
    - Two Double Flow Low Pressure Turbines
  - Design Rating: 800 MW
  - Inlet Temperature: $1000^0$F/$1000^0$F
  - Speed: 3600 RPM
  - Operating Time: 24 Years

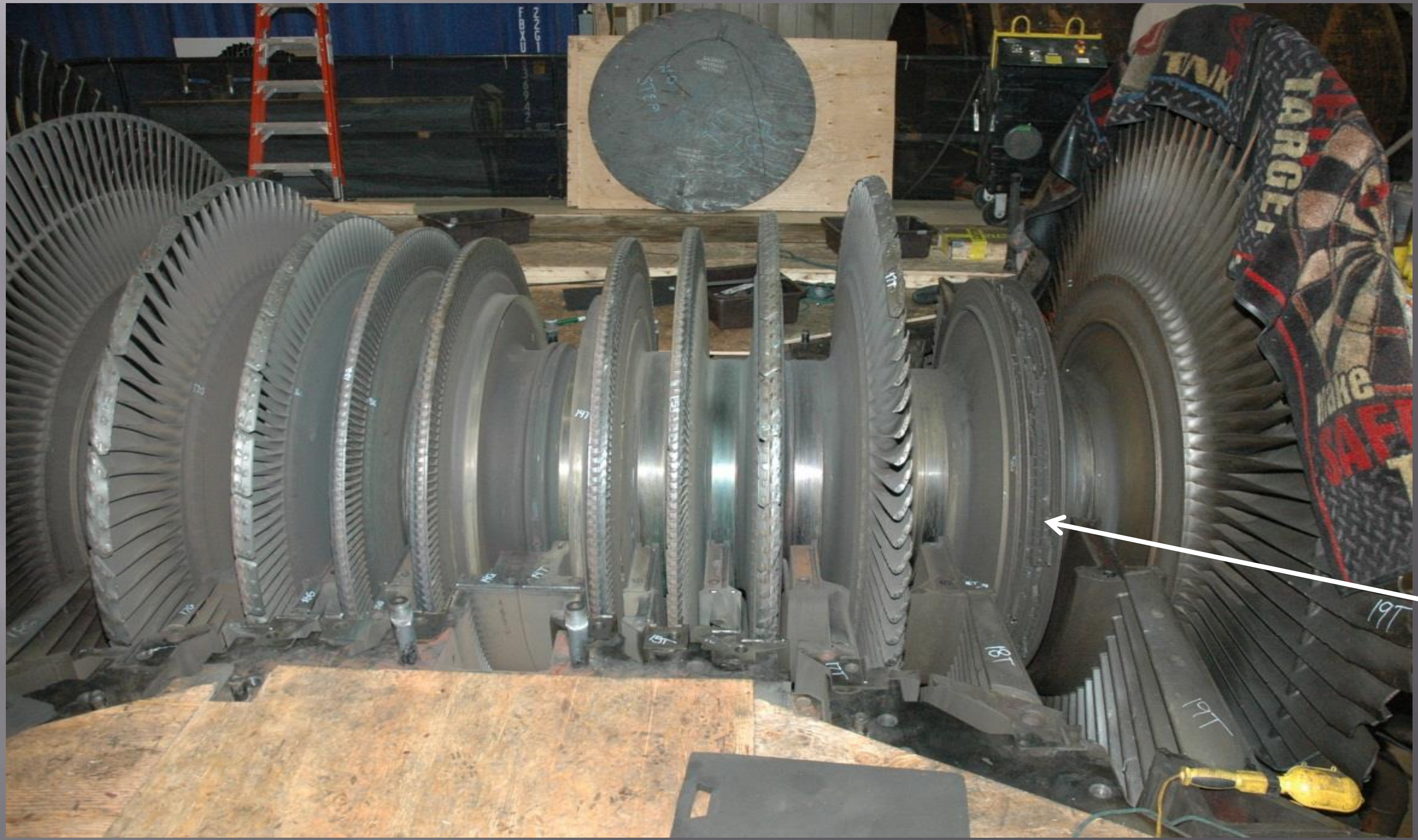
# Failure Event

- Severe Vibration Encountered During Overspeed Test
  - Unit Tripped
  - Coast Down was Less than 2 ½ Minutes
  - External Damage was Extensive
    - Exciter Shaft and Generator Shaft Fractured
    - Pedestals Torn from Foundation
    - Casing Bolts Sheared Off

# Teardown Observations

- One L-1 Low Pressure Turbine Disk had Fractured Circumferentially and Radially through Multiple Finger Pinned Blade Attachments
  - Approximately 60% of Blades Missing
  - Imbalance Estimated at 1500 lbs.
- Remaining Three L-1 Disks Exhibited Stress Corrosion Cracks in Finger Pinned Blade Attachments
- Significant Internal Damage to all Turbine Modules

# Teardown Observations



Fractured L-1 Disk

# Teardown Observations

# RCA Findings

- L-1 Disk Fractures Due to Caustic Stress Corrosion
  - Initiated at Pin Holes and Finger Ledges
- Steam Chemistry Within OEM Requirements
- No Material Anomalies
- No "Abnormal" Operating Conditions

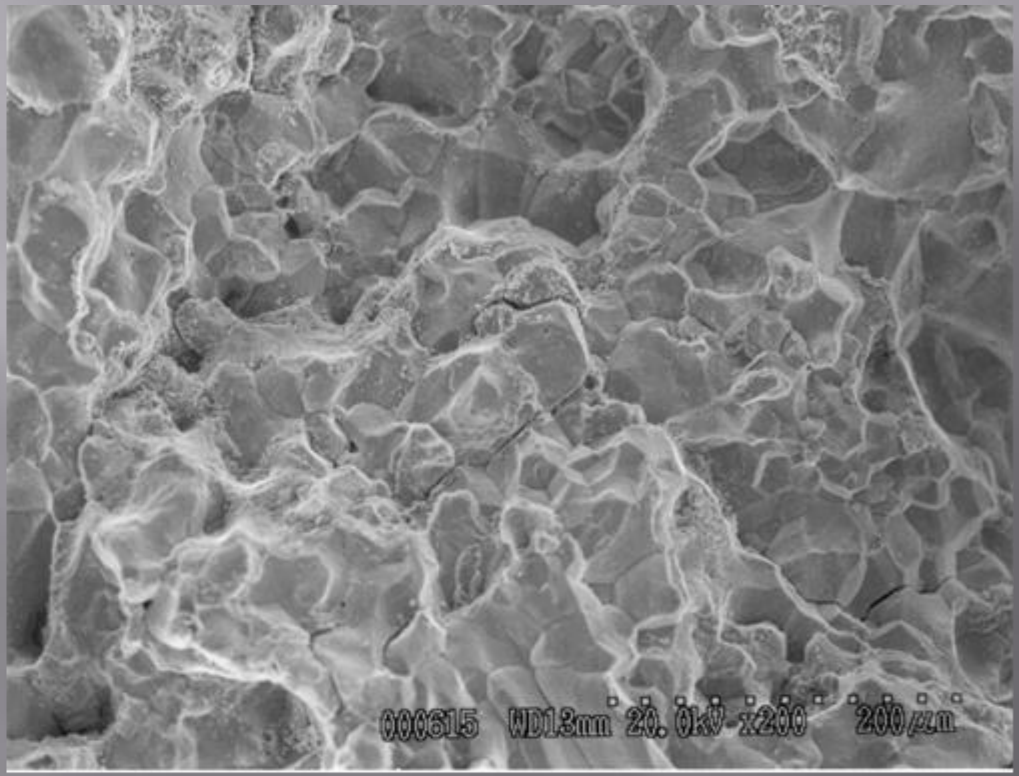
# RCA Findings

FRACTURES THROUGH FINGERS

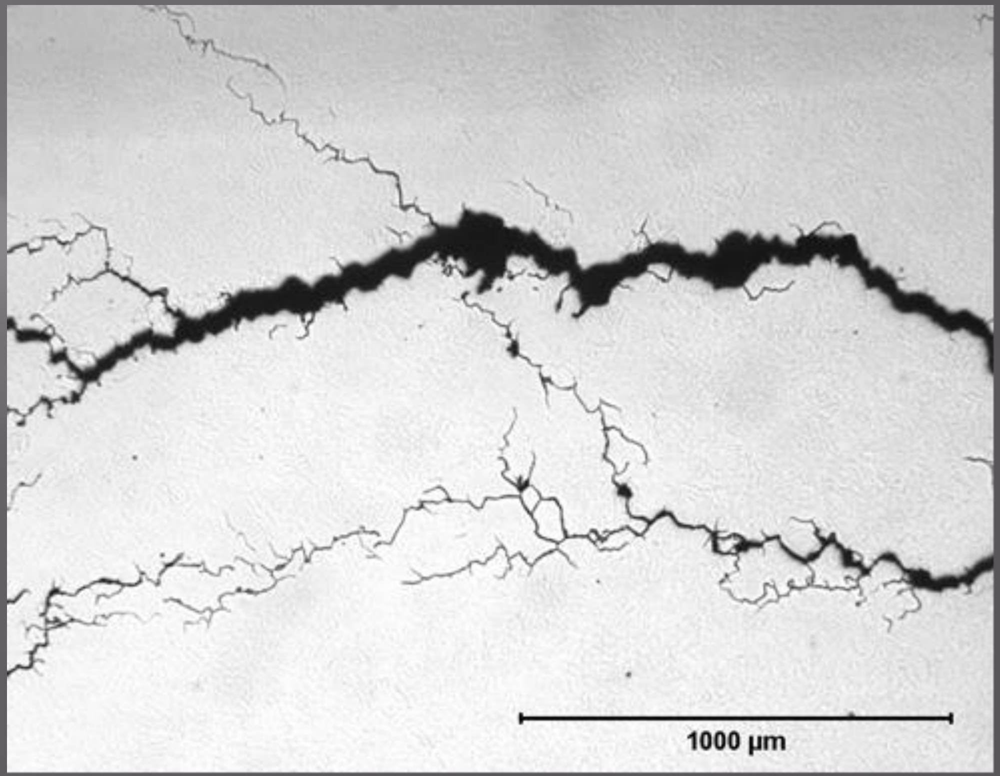

SCC CRACKS AT LEDGES AND PIN HOLES

# RCA Findings

INTERGRANULAR FRACTURE

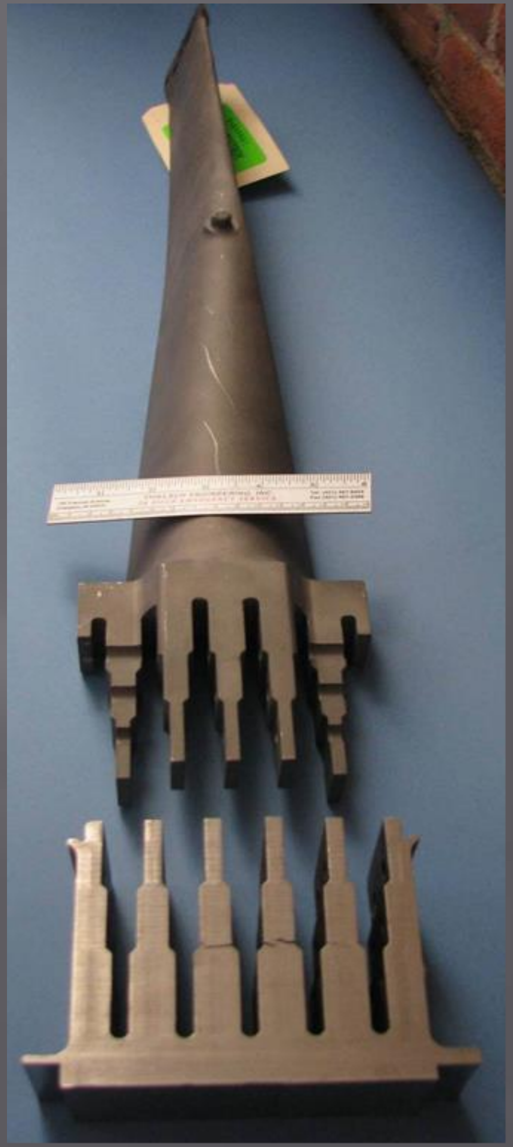



CRACK BRANCHING



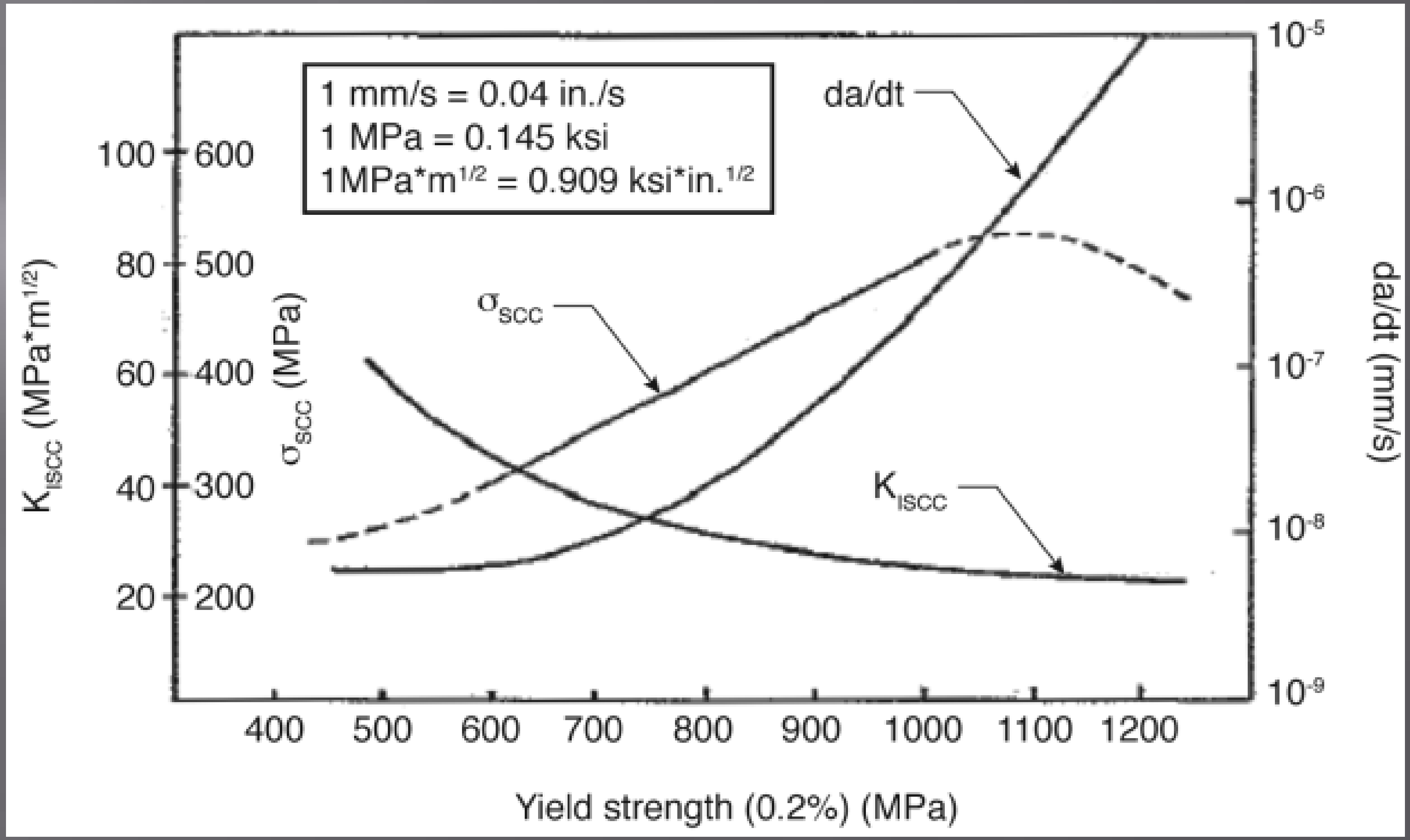
# RCA Findings

- Blade Attachment Design Requires Blade Removal for Non-Destructive Examination of Disk Fingers
  - Limit on Number of Times Blades may be Removed



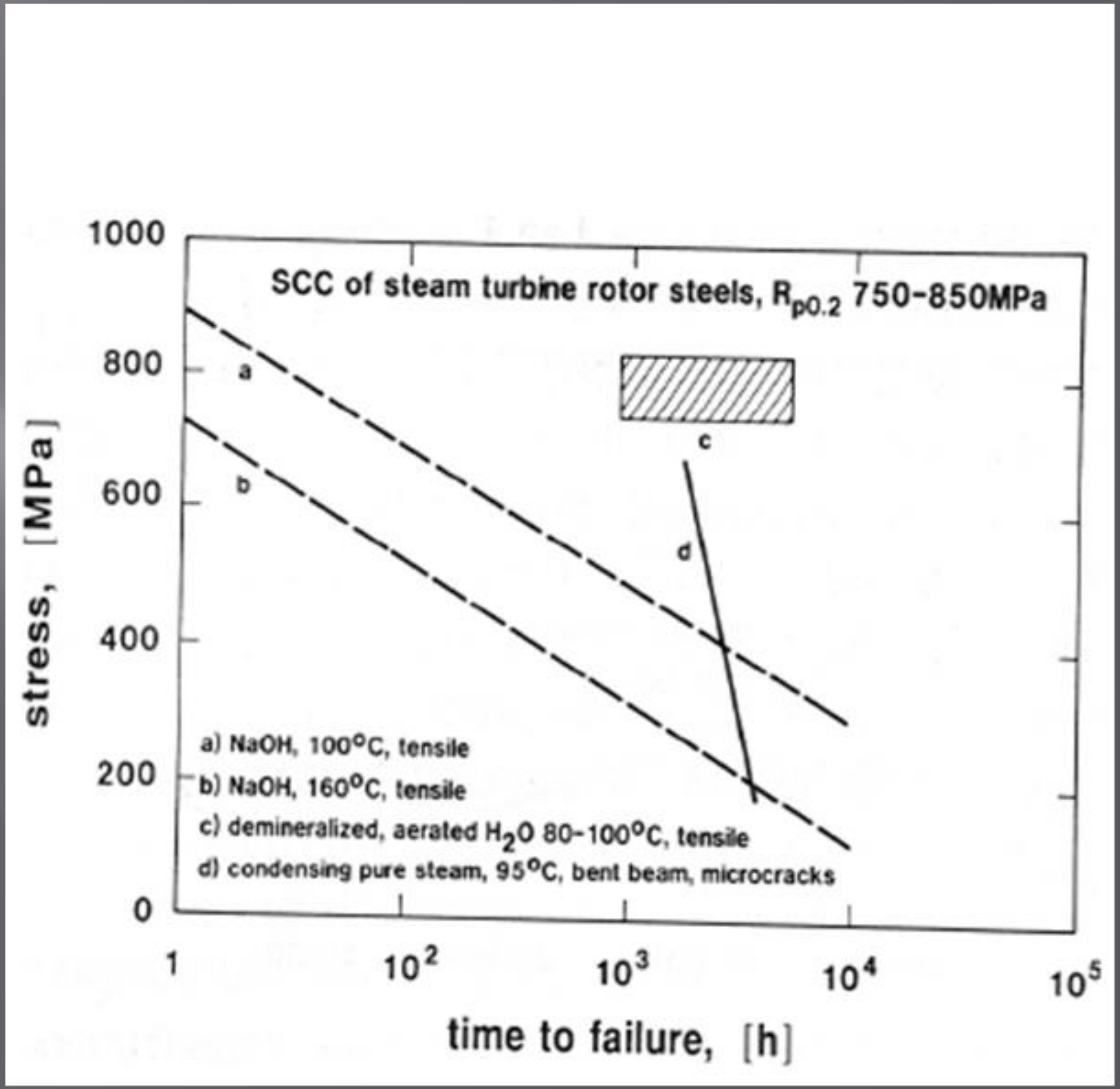
# Stress Corrosion Cracking

- Variables
  - Material
  - Stress
  - Environment
  - Time



# Stress Corrosion Cracking

- Operating Time Affects Stress Corrosion Cracking
  - Concentration of Precipitates in Crevices
    - Shut Down/Start-Up
    - Partial Loading
  - Initiation and Propagation



# Post Event Repairs

- New 12Cr Stainless Steel L-1 Low Pressure Turbine Disks Installed
- Disk/Blade Geometry Modified
  - Reduce Stress Concentrations
- Finger Pinned Root Attachments Shot Peened after Final Machining

# Conclusions

- "Good" Steam Chemistry Does Not Insure Against Stress Corrosion Cracking of Low Alloy Disks
- Stress Corrosion Cracking a Function of Operating Time and Start-up/Shutdowns
  - Older Units at Greater Risk
- Non-Destructive Inspection Crucial
- For Repairs/Retrofits, 12 Cr Stainless Steel and Shot Peening Significantly Improve SCC Resistance